Assessment of Contractional Deformation Rates of the Mt. Diablo Fold and Thrust Belt, Eastern San Francisco Bay Region, Northern California

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Introduction

The seismic hazards of the eastern San Francisco Bay region typically are considered to be dominated by several active dextral faults east of the San Andreas fault at the latitude of Livermore Valley. In general, the seismic hazards associated with contractional faults have been weighed to be approximately 1 order of magnitude less important than that posed by the dextral faults. However, contractional deformation in the Livermore Valley and Mt. Diablo region, referred to as the Mt. Diablo fold and thrust belt, appears to be driven by the interaction of two of the dextral faults. Specifically, the fold and thrust belt lies within a 20-km-wide restraining left-stepover between the Greenville and Concord faults. North-northeast-south-southwest directed late Cenozoic crustal shortening within the Mt. Diablo fold and thrust belt occurred at the substantial rate of 3.4 $\pm$ 0.9 mm/yr (Unruh and Sawyer, 1997), comparable to the creep rate of 3 $\pm$ 1 mm/yr on the Concord fault and to the permissive slip rate of $\geq$2 mm/yr on the Greenville fault (Unruh and Sawyer, 1998). This indicates that northwest dextral shear is conserved by contractional deformation in the stepover region and, therefore, suggests that the seismic hazards associated with the Mt. Diablo fold and thrust belt may be commensurate to the hazards posed by the dextral faults.

The goal of the present study is to investigate the location, extent, deformation rates, and seismic potential of late Quaternary surface and blind contractional faults in the Livermore Valley-Mt. Diablo area, eastern San Francisco Bay region. The study addresses these goals through a program of photo-geologic interpretation, morphometric analyses, and field mapping and surveying.

Investigations Undertaken

We have obtained several sets of black-and-white and color, conventional aerial photographs that provide stereoscopic coverage of the southwest flank of Mt. Diablo and of Livermore Valley. Surficial deposits and potentially fault-related geomorphic features were identified, mapped, and compiled on 1:24,000 topographic maps (e.g., Figure 1). These maps have been used for our initial morphometric analyses. We have contacted several earth scientists, dendrochronologists, and flood-control personnel obtaining information relevant to our research project. Mr. Sawyer presented our preliminary findings to consultants and developers of the North Livermore and Tassajara Valley community projects; planned communities of 15,000 and 6,000 single-family dwellings and associated infrastructure (respectively) amidst the Mt. Diablo fold and thrust belt. Easily accessible features identified on the aerial photographs were examined during preliminary field reconnaissance. A sample of charcoal collected from a terrace along Arroyo Las Positas was submitted for ^{14}C dating. We have made and continue to make an exhaustive effort to obtain permission to access 38 private parcels of land in order to examine additional features, collect more dateable materials, describe soils and surficial deposits, and conduct detailed topographic surveys.

Results

Based on our work performed to date, we find the following:

1) Quaternary contractional deformation has and apparently is encroaching on the late Cenozoic Livermore basin and, in the process, has formed 4 discrete structural sub-basins separated by geomorphically prominent Quaternary folds;
2) The Livermore basin is bisected by the Livermore fault, which is expressed by fault scarps, lineaments, a 5 km or less deflection of Arroyo Mocho, and uplifted alluvial surfaces. Transverse passes cross the alluvial surfaces decrease in elevation to the northwest (Figure 2), and are interpreted to represent as many as 5 windgaps related to the ancestral Arroyo Mocho drainage system. These observations are consistent with a northwest-plunging topographically defined anticline, suggesting a strong, perhaps dominant, style of contractional deformation on the Livermore fault. The highest windgap is approximately 40 m above the pre-diversion channel of Arroyo Mocho (Figure 3) and is cut into deposits constrained to be younger than the 600-450 ka old upper Livermore 'gravel' (Herd and Brab, 1980) and older 350-300 ka old soils developed on terrace deposits (Shlemon et al., 1980). Thus, if stream incision is a proxy for vertical deformation,

than the anticline delineating the Livermore fault has been growing at a preliminary approximate uplift rate of 0.1 ± 0.04 mm/yr. Furthermore, the anticline appears to have propagated to the northwest at an average rate of 1 mm/yr or more during the mid to late Quaternary; and

3) The Las Positas fault, defining the southern margin of Livermore Valley, appears to have tectonically beheaded and offset a drainage channel associated with the second highest windgap crossing the 'Livermore anticline' 500 to 800 m in a left-lateral sense (Figure 2). This preliminary hypothesis supports a sinistral slip rate of 1 mm/yr or greater on the Las Positas fault, which is consistent with the slip rate of 0.4 to 1.6 mm/yr estimated by Sawyer and Kelson (1994) from data in Herd (1977), Carpenter and Clark (1982) and Clark et al. (1984) and from photogeologic interpretations of offset marker beds in the Livermore gravel.

Remaining tasks to be accomplished during the final months of the study include completion of field investigations and preparation of longitudinal profiles of terraces along Tassajara Creek, Arroyo Las Positas, and of a windgap near the Highland School site that extend across Quaternary folds. This study is not intended to produce seismic, geodetic, or similar processed data.

Non-Technical Summary

The goal of this study is to document the location and rates of deformation associated with the Mt. Diablo fold and thrust belt. The fold and thrust belt is an active system of hidden or "blind" thrust faults beneath the cities of Livermore and Pleasanton. Our study will contribute to the understanding of seismic hazards in the eastern San Francisco Bay region. This study is timely considering the rapid urbanization of the Livermore Valley. In an attempt to reduce earthquake hazards, we have presented our preliminary results to individuals responsible for the two largest residential developments in the region.

Reports Published

Not applicable.

References

Carpenter, D.L. and Clarke, R.J., 1982, Geologic studies for seismic hazard assessment, Las Positas fault: Proc. Conf. on Earthquake Hazards in the Eastern San Francisco Bay Area, P. 147-154.

Clark, M.C., Harms, K.K., Leinkaemper, J.J., Harwood, D.S., Lajoie, K.R., Matti, J.C., Perkins, J.A., Rymer, M.J., Sarna-Wojcicli, A.M., Sharp, R.V., Sims, J.D., Tinsely, J.C., III, and Ziony, J.I., 1984, Preliminary slip-rate table and map of late-Quaternary faults of California: USGS Open-File Report 84-106.

Crane, R.C., 1995, Geologic map of the Livermore and the Altamont 7.5' quadrangles……..

Ford, R.S. and Hills, E.E., 1974, Evaluation of ground water resources: Livermore and Sunol Valleys: CA DWR Bulletin No. 118-2, 153 p.

Herd, D.G., 1977, Geologic map of the Las Positas, Greenville, Verona faults, eastern Alameda County, California: USGS Open-File Report 77-689.

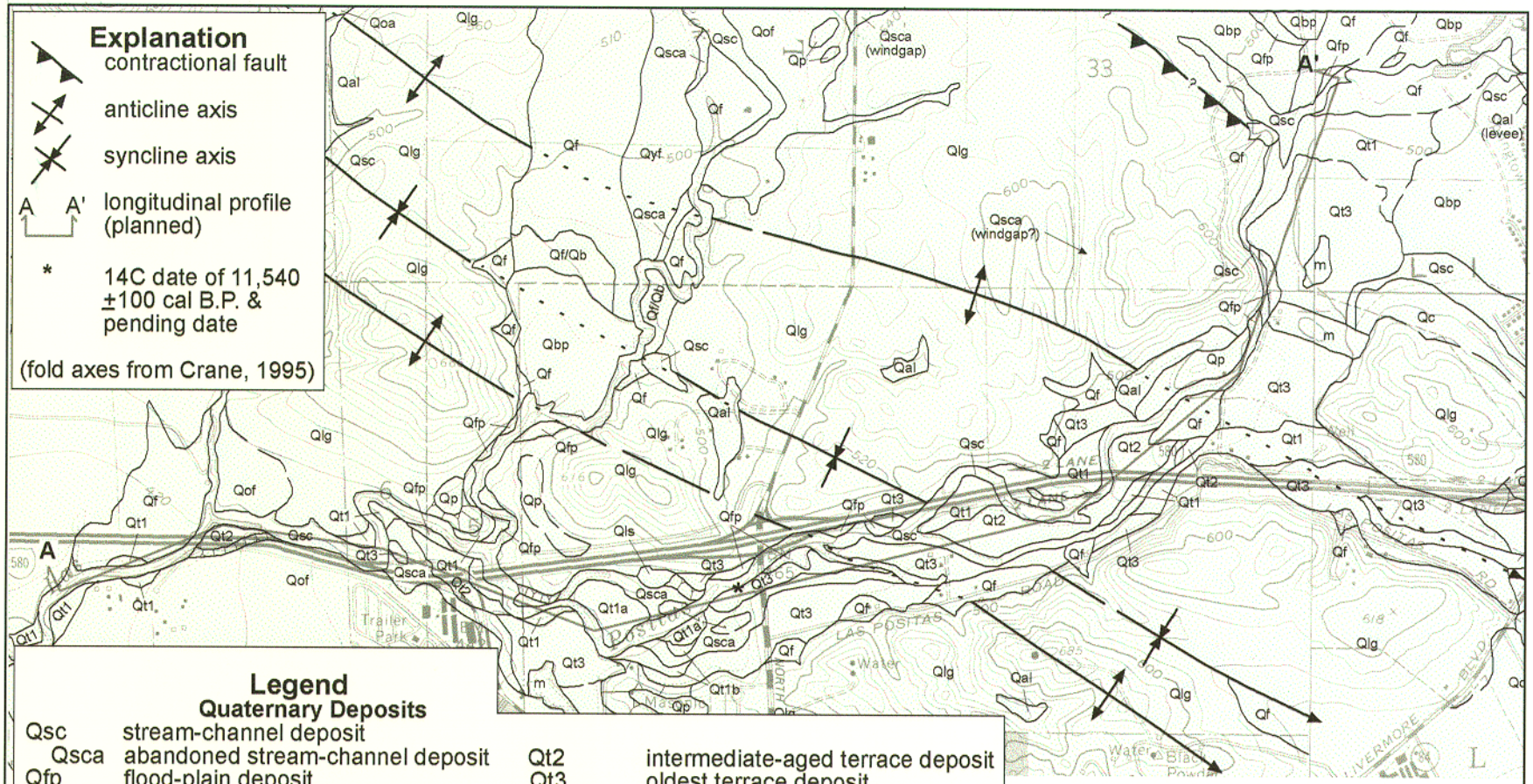
Herd, D.G. and Brabb, E.E., 1980, Faults at the General Electric test reactor site Vallecitos Nuclear Center, Pleasanton, California, A summary review of their geometry, age of last movement, recurrence, origin, and tectonic setting and the age of the Livermore gravels: USGS Admin. Report, 77 p.

Sawyer, T.L. and Kelson, K.I., Paleoseismic investigation of the Las Positas fault, eastern San Francisco Bay Region, California: (unpublished) proposal to USGS, NEHRP, 30 p.

Shlemon, R.J., Wright, R.H., and Verosub, K.L., 1980, Late Quaternary multiple buried paleosols, Vallecitos Valley, Alameda Co., California: GSA Absts w/ Programs, v. 12, no. 3, p.152.

Unruh, J.R. and Sawyer, T.L., 1997, Assessment of blind seismogenic sources, Livermore Valley, eastern San Francisco Bay region: Final Technical Report submitted to USGS, NEHRP, 88 p.

Unruh, J.R. and Sawyer, T.L., 1998, Paleoseismic investigation of the northern Greenville fault, eastern San Francisco Bay region: Final Technical Report submitted to USGS, NEHRP, 27 p.



Legend

Quaternary Deposits

Qsc	stream-channel deposit		
Qsca	abandoned stream-channel deposit	Qt2	intermediate-aged terrace deposit
Qfp	flood-plain deposit	Qt3	oldest terrace deposit
Qal	undifferentiated alluvium	Qof	oldest alluvial-fan deposit
Qbp	basin-fill alluvium w/ patterned ground	Qoa	older alluvium
Qyf	younger alluvial-fan deposit	Qp	deposit associated w/ pediment
Qf	intermediate-aged alluvial-fan deposit	Qlg	Livermore 'gravel'
Qt1	young terrace deposit		
Qt1a	youngest terrace deposit	m	modified
Qt1b	younger terrace deposit		

Scale 1:24,000

0 .5 1 km

0 .5 1 mi

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Surficial geologic map along Arroyo Las Positas between Livermore and Springtown showing alignment of planned longitudinal stream profile.

Figure 1

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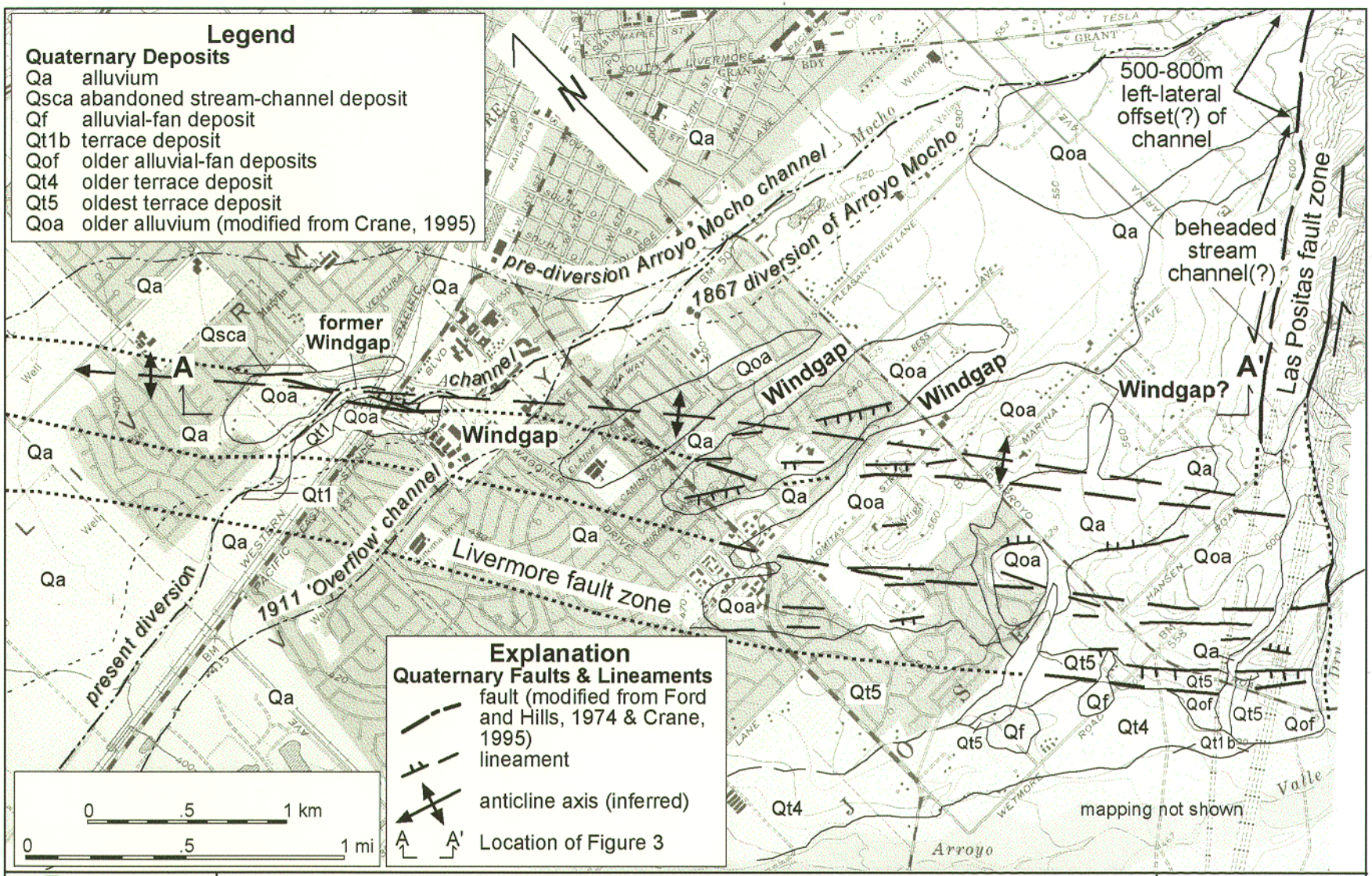

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Surficial geologic map of central Livermore Valley

Figure 2

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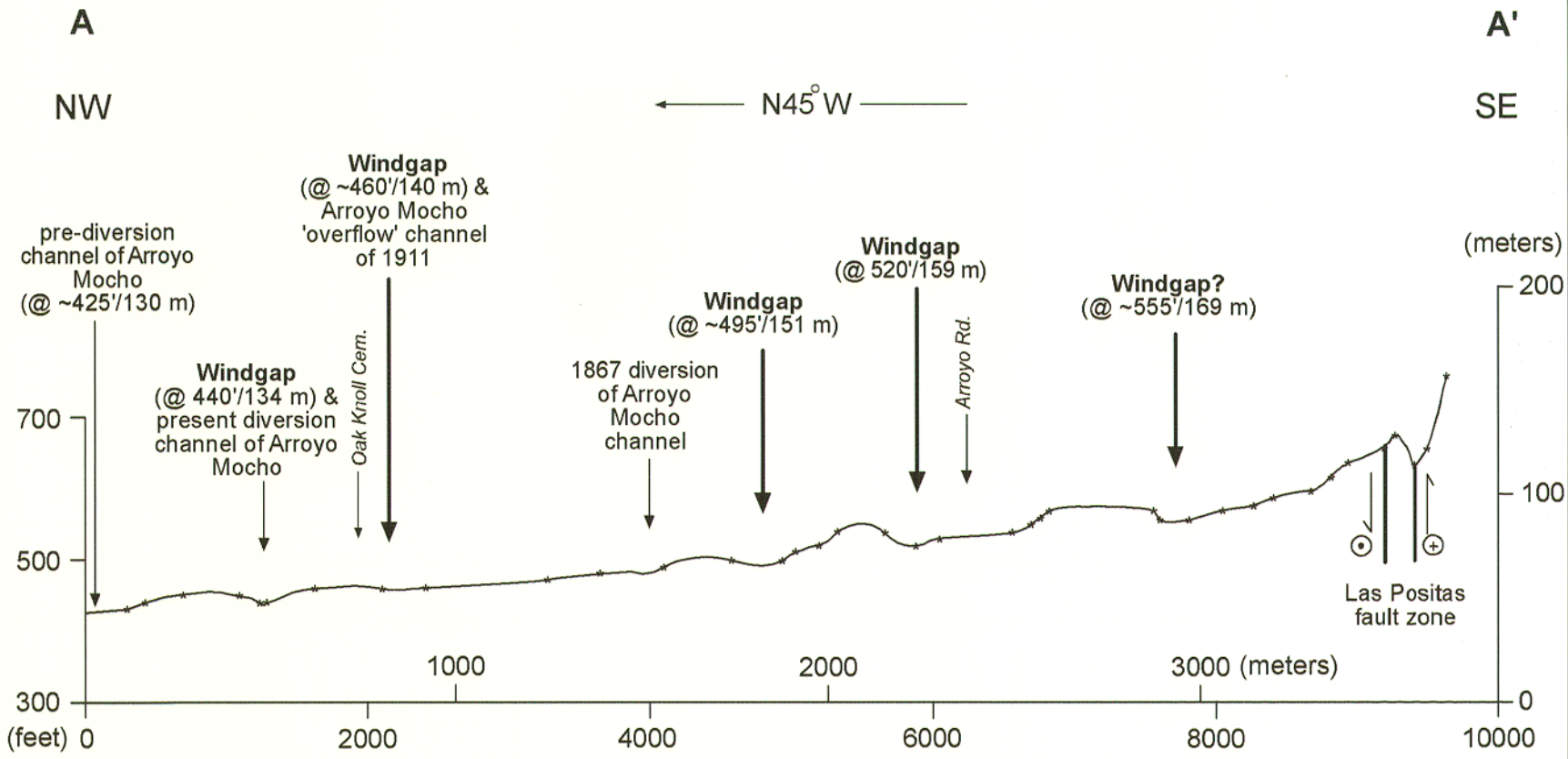

Vertical exaggeration = 10X

See Figure 2 for profile location

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Topographic profile of possible windgaps along the Livermore fault, Livermore Valley

Figure 3

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